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TP 8326E

TRAFFIC SIGNALS

Left–Turn Phasing, Timing and Displays, Vehicle Clearance Intervals

RECOMMENDED PRACTICE

Summary Report

Prepared for
Transportation
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by
DeLeuw Cather Canada Ltd.

MARCH 1987

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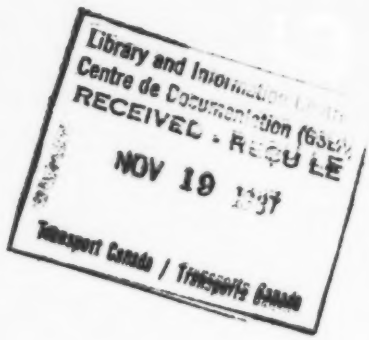

by

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March 1987

The contents of this report reflect the views of the authors and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

This report does not constitute a standard, specification or regulation.

Ce document est également disponible en français: "Programmation des feux de virage à gauche prioritaire - Pratiques recommandées", TP 8326F.

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17. Abstract

This report summarizes the results of an evaluation of responses to a series of questionnaires and of meetings with practising traffic engineers across Canada with respect to the timing and phasing of traffic signals, including vehicle clearance intervals, as well as the signal head displays that are associated with the various left-turn phasing alternatives.

The report provides recommendations to assist the Canadian Council on Uniform Traffic Control Devices in the development of uniform standards for the application of practices and devices in the foregoing aspects of the use of traffic signals.

Also available in French — TP 8326F "Programmation des feux de virage à gauche prioritaire — Pratiques recommandées".

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17. Résumé

Le présent rapport résume les résultats de l'évaluation faite des interviews et des questionnaires auxquels ont répondu les ingénieurs du trafic urbain, un peu partout au Canada, en ce qui concerne les normes applicables aux feux de virage à gauche, à la signalisation correspondante et à la programmation.

De plus, ce rapport formule diverses recommandations destinées à guider le Conseil canadien de normalisation des dispositifs de régulation de la circulation dans la mise en oeuvre des méthodes et des dispositifs applicables.

Également disponible en français — TP 8326F "Programmation des feux de virage à gauche prioritaire — Pratiques recommandées".

Sommaire de "Traffic Signals — Left-Turn Phasing, Timing and Displays, Vehicle Clearance Intervals — Recommended Practice", mars 1987, TP 8226E.

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1. INTRODUCTION

This is the summary report of the second phase of a project, the first phase of which was completed in March 1984 with the publishing of the report entitled "Traffic Signals - Left-Turn Phasing and Displays, Vehicle Clearance Intervals, Flashing Operation - State-of-the-Art" (Transportation Development Centre, TP 5324E).

In March 1985, DeLCan was authorized to undertake the second phase of the project, which had as its objectives:

- the development of standard practices to be used in the determination of vehicle clearance intervals and the need for and timing of left-turn phases in the operation of traffic signals;

- the development of standardized configurations for traffic signal indications to be used to control left-turn movements at traffic signal controlled intersections.

Specifically, the project was intended to produce a recommended practice for:

- determining the need for a left-turn phase in a traffic signal phasing sequence and the period of operation;

- the timing of left-turn phases;

- the timing of clearance intervals;

- the traffic signal indications that should be displayed for each of the left-turn phasing alternatives.

At the outset of the project, a study group was formed. This study group comprised practising traffic engineers from provincial and municipal agencies and representatives from Transport Canada, the Canada Safety Council and Mohawk College. Most of the study group was involved in both phases of the project.

Questionnaires and meetings with the study group members were used to supplement the research from the first phase of the project as a means of developing a recommended practice for the timing and phasing of traffic signals as well as for the signal indication displays that are associated with the various left-turn phasing alternatives. Recent research was used to develop a recommended practice for the timing of vehicle clearance intervals in traffic signals.

A basic questionnaire and the responses thereto gave rise to a number of issues which were summarized and presented to the study group.

Meetings were held in Vancouver (September 30, 1985), Ottawa (April 8, 1986), and Toronto (September 29, 1986) to consider the summaries of the responses to the questionnaires and the issues arising therefrom.

Most but not all of the issues were resolved; accordingly, the consultant assessed the valuable information provided by the study group participants and developed proposals for the various elements which comprise the objectives of the project.

2. WARRANTS FOR LEFT-TURN PHASING

A warrant for left-turn phasing has been developed which provides an interrelationship of the number of lanes at an intersection, the ratio of the "green" signal time to the cycle length (G/C), the left-turn traffic volume and the opposing (through plus right-turn) traffic volume.

The warrant for left-turn phasing is based on geometric and traffic factors as well as collision factors.

2.1 Geometric and Traffic Factors

The following equation can be used to determine if and when a left-turn phase is warranted:

$$C_{LT} = 1400\ G/C - (f)Vo + LT_A$$

Where:

C_{LT} = the capacity of the left-turn lane during a "permissive" green phase

(f) = a factor to represent the approximate gap probability and acceptance

With an opposing flow in	1	2	3	4	lanes
(f) =	1.0	0.625	0.5	0.44	

Vo = total opposing volume (includes opposing through lanes, shared lanes and right turns where channelization does not exist)

C = cycle time (seconds)

G = effective green interval for the opposing traffic flow (seconds)

LT_A = the number of vehicles turning left on amber on the approach under consideration.

Note that LT_A is a function of the opposing flow (if the opposing flow is at capacity, the opportunity to turn left may be minimal) but should also reflect the behaviour of motorists in the community to which the analysis is being applied.

When a value of 1400 is applied, it can safely be assumed that some vehicles will clear on amber. In large cities, the value of two vehicles per cycle has typically been used. In smaller municipalities, the value of one vehicle per cycle may be more appropriate.

If the left-turn capacity as estimated from the equation on the previous page exceeds the left-turn demand, as measured or as forecast for some future year/time, a separate left-turn phase is not warranted.

2.2 Collision Factors

With respect to the collision experience, a local rate should be determined for left-turn collisions and the experience at a particular intersection should be compared to that rate. If it exceeds the rate, there is support for a left-turn phase.

Where a local rate is not easily derived, the following guidelines should be used to determine the need for a left-turn phase:

a) for one approach, four left-turn collisions in one year or six in two years;

b) for both approaches, six left-turn collisions in one year or 10 in two years.

3. TIMING LEFT-TURN PHASES

There are a number of traffic signal timing methods currently in use and traffic engineers in most provinces and large municipalities have adopted a method which suits their needs. A simplified method in the form of a table relating the number of seconds per vehicle (headway) to a "level of service" is proposed to provide guidelines to officials in small to medium sized municipalities.

Although level of service and its relationship to capacity is characterized in different ways depending upon the methodology (1965 Highway Capacity Manual, 1985 Highway Capacity Manual, etc.), for the purposes of this report, a qualitative description of the level of service is adequate. Accordingly, the following is based on the descriptions of levels of service in the 1965 Highway Capacity Manual and the Ontario Ministry of Transportation and Communications methodology. The descriptions are included here solely to provide an appreciation for the term "level of service".

LEVEL OF SERVICE "A" - No signal phase is fully utilized by traffic and no vehicle waits longer than one red indication. The approach appears open, turning movements easily made and drivers have freedom of operation.

LEVEL OF SERVICE "B" - An occasional signal phase is fully utilized and many phases approach full use. Many drivers begin to feel somewhat restricted within platoons of vehicles approaching the intersection.

LEVEL OF SERVICE "C" - The operation is stable with more frequent fully utilized signal phases. Drivers feel more restricted and occasionally may have to wait through more than one red signal indication and queues may develop behind turning vehicles.

LEVEL OF SERVICE "D" - The motorist experiences increasing restriction and instability of flow. There are enough cycles with lower demand to permit occasional clearance of developing queues and prevent excessive back-ups.

LEVEL OF SERVICE "E" - This represents capacity. There are long queues of vehicles waiting upstream of the intersection and delays to vehicles may be more than one signal cycle.

Since it is not normal practice to provide a level of service better than C for a left-turn phase, Table 1 provides suggested values for levels of service C, D and E.

Table 1
Left-Turn Phase Timing

	Number of Seconds		
	Small Urban Area	Medium Urban Area	Large Urban Area
Level of Service "C"			
First two vehicles	13	12	10
Each additional vehicle	3.0	2.5	2.25
Level of Service "D"			
First two vehicles	11	10	8
Each additional vehicle	2.5	2.25	2.25
Level of Service "E"			
First two vehicles	9	8	7
Each additional vehicle	2.5	2.25	2.0

In large municipalities, the minimum length of a left-turn phase should be not less than five seconds. In small municipalities, the minimum length of a left-turn phase should be not less than seven seconds.

A higher minimum value should be established, if necessary, based on:

- field studies;
- unusually wide intersections;
- the case where left-turn detectors are set back from the stop line;
- unusually high number of heavy vehicles;
- the grade on the left-turn approach to the intersection;
- a rural environment.

4. TIMING CHANGE INTERVALS

The proposed recommended practice as described in "Determining Vehicle Change Intervals" (ITE Technical Committee 4A-16, ITE Journal, May 1985) was used (although the proposal has not been adopted as a recommended practice by ITE) as the basis for developing tables of values which can be applied as guidelines to determine the timing of the change interval - amber (yellow) plus "all-red", if used - in a traffic signal.

The formulae contained in the aforementioned ITE article have been converted to allow the use of the terms "amber" and "kilometres per hour".

Table 2 provides the values which should be applied for the amber clearance portion of the change interval, depending on the speed and the grade on the approach to the intersection. No values below 3.0 seconds are provided as this value is considered to be the minimum value that should be used under any circumstances.

As suggested in the ITE article, "While the determination of the slope of roadway approaches is rather straightforward, the remaining variable, V (vehicle speed), can be more difficult to determine. The speed is generally taken to be that represented by a locally chosen precenttle of approach speeds, usually the 85th percentile, although it may be possible to use the posted speed limit as the approach speed. Such a policy may not be unreasonable given that drivers approaching at higher speeds are violating the law. Care should be taken to assure that the speed limit is reasonable. Determining the approach speed to use for timing the yellow interval for protected turn phases is more complicated than for through phases due to the changing approach speed of vehicles preparing to make a turn. Turning vehicles may be either approaching at through vehicle speed and slowing down to a safe turning speed, or accelerating from a stop condition in a queue. Appropriate selection of approach speed can allow one to produce a good approximation of the timing needed."

Following Table 2 are the guidelines suggested for determining the length of the "red clearance interval".

As indicated in the ITE article, "To a substantial extent, the need for red clearance intervals is predicated on the local jurisdiction's policy regarding the necessity of an absolute provision of time for vehicles that entered on yellow to clear the area of conflict before the right-of-way is reassigned. As vehicles may legally enter the intersection during the display of the yellow indication, the yellow interval is not a clearance interval..." and "If it is the policy of the local agency to provide clearance time, the traditional practice has been to either add the time to the yellow interval, or to use what has previously been called the "all red interval"" (referred to as the red clearance interval). It is proposed by ITE Committee 4A-16 that the policy of ITE be that if clearance time is to be provided, it should be in the form of a red clearance interval.

Table 2
Amber Portion of Change Interval
(in seconds)

Grade (%)		Approach Speed in km/h															
		25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	10
	10	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.1	3.3	3.4	3.6	3.8	4.0	4.1	4.3	4.5
	8	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.2	3.4	3.6	3.7	3.9	4.1	4.3	4.5	4.6
	6	3.0	3.0	3.0	3.0	3.0	3.0	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.8	
	5	3.0	3.0	3.0	3.0	3.0	3.0	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	
UPHILL	4	3.0	3.0	3.0	3.0	3.0	3.0	3.2	3.4	3.6	3.8	4.1	4.3	4.5	4.7	4.9	5.1
	3	3.0	3.0	3.0	3.0	3.0	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.6	4.8	5.0	5.2
	2	3.0	3.0	3.0	3.0	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.7	4.9	5.1	5.3
	1	3.0	3.0	3.0	3.0	3.0	3.2	3.5	3.7	3.9	4.1	4.3	4.6	4.8	5.0	5.2	5.4
	0	3.0	3.0	3.0	3.0	3.1	3.3	3.5	3.8	4.0	4.2	4.4	4.7	4.9	5.1	5.4	5.6
	-1	3.0	3.0	3.0	3.0	3.1	3.4	3.6	3.8	4.1	4.3	4.5	4.8	5.0	5.3	5.5	5.7
	-2	3.0	3.0	3.0	3.0	3.2	3.5	3.7	3.9	4.2	4.4	4.7	4.9	5.2	5.4	5.6	5.9
	-3	3.0	3.0	3.0	3.0	3.3	3.5	3.8	4.0	4.3	4.6	4.8	5.1	5.3	5.6	5.8	6.1
DOWNHILL	-4	3.0	3.0	3.0	3.1	3.4	3.6	3.9	4.2	4.4	4.7	4.9	5.2	5.5	5.7	6.0	6.3
	-5	3.0	3.0	3.0	3.2	3.5	3.7	4.0	4.3	4.6	4.8	5.1	5.4	5.6	5.9	6.2	6.5
	-6	3.0	3.0	3.0	3.1	3.6	3.8	4.1	4.4	4.7	5.0	5.3	5.5	5.8	6.1	6.4	6.7
	-8	3.0	3.0	3.2	3.5	3.8	4.1	4.4	4.7	5.0	5.3	5.6	5.9	6.2	6.5	6.8	7.2
	-10	3.0	3.0	3.4	3.7	4.0	4.4	4.7	5.1	5.4	5.7	6.1	6.4	6.7	7.1	7.4	7.7

amber clearance interval: $y = t + \frac{V}{2a + 2Gg}$

Where:
- t = 1.0 second perception time
- V = approach speed in km/h
- a = (11.0 km/h)/sec (deceleration rate)
- G = (35.3 km/h)/sec (acceleration rate due to gravity)
- g = grade of approach in percent divided by 100 (downhill is negative)

Source: adapted from "Determining Vehicle Change Intervals", ITE Journal, May 1985.

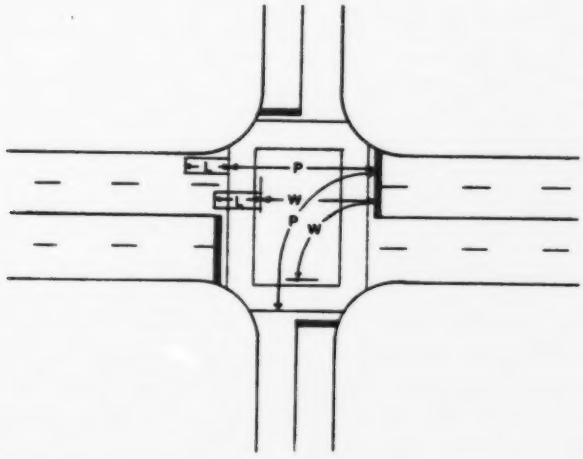
Values have been rounded from two significant digits to one significant digit by rounding to the next highest 0.1 from any value of 0.03 to 0.09.

The red portion of the change interval (or red clearance interval) is dependent on the selection of the appropriate "case" and its associated "clearing distance". In this regard, there are three "cases" as described in the following. In the equations, the distances P, L and W are as described and illustrated below.

W = Width of the intersection, in metres, measured from the near side stop line to the far side edge of the conflicting traffic lane along the actual vehicle path (a curved line in the case of a left turn).

P = Width of the intersection, in metres, measured from the near side stop line to the far side of the farthest conflicting pedestrian crosswalk along the actual vehicle path (a curved line in the case of a left turn).

L = 6.0 m average vehicle length (ITE uses a 6.1 m length).



The three "cases" are:

Case 1: Clearing distance is based on no pedestrian traffic - use (W + L)

"All red" portion of the change interval = (r) = $3.6 \frac{(W + L)}{V}$

Case 2: Clearing distance is based on some probability of pedestrian traffic - use P.

"All red" portion of the change interval = (r) = $3.6 \frac{P}{V}$

Use the value from Case 1 and Case 2 which yields the largest value.

Case 3: Clearing distance is based on significant pedestrian traffic or where pedestrian signals have been provided -use (P + L).

"All red" portion of the change interval = (r) = $3.6 \frac{P + L}{V}$

If there is any doubt as to which case to use, base the clearing distance on Case 3.

Table 3 provides the values which should be applied for the all-red portion of the change interval depending on the "clearing distance" and the speed. Thus, for a given intersection approach, the "clearing distance" to be used for determining the clearance interval must first be established (i.e., Case 1, Case 2 or Case 3). Once the clearing distance is established, enter the table with the clearing distance and the approach speed, and the value for the all-red portion of the change interval is given.

Table 3
All-Red Portion of Change Interval
(in seconds)

Clearing Distance (m)	Speed (km/h)										
	25	30	35	40	45	50	60	70	80	90	100
12.0	1.7	1.4	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
13.5	1.9	1.6	1.4	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0
15.0	2.2	1.8	1.5	1.4	1.2	1.1	1.0	1.0	1.0	1.0	1.0
16.5	2.4	2.0	1.7	1.5	1.3	1.2	1.0	1.0	1.0	1.0	1.0
18.0	2.6	2.2	1.9	1.6	1.4	1.3	1.1	1.0	1.0	1.0	1.0
19.5	2.8	2.3	2.0	1.8	1.6	1.4	1.2	1.0	1.0	1.0	1.0
21.0	3.0	2.5	2.2	1.9	1.7	1.5	1.3	1.1	1.0	1.0	1.0
22.5	3.2	2.7	2.3	2.0	1.8	1.6	1.4	1.2	1.0	1.0	1.0
24.0	3.5	2.9	2.5	2.2	1.9	1.7	1.4	1.2	1.1	1.0	1.0
25.5	3.7	3.1	2.6	2.3	2.0	1.8	1.5	1.3	1.1	1.0	1.0
27.0	3.9	3.2	2.8	2.4	2.2	1.9	1.6	1.4	1.2	1.1	1.0
28.5	4.1	3.4	2.9	2.6	2.3	2.1	1.7	1.5	1.3	1.1	1.0
30.0	4.3	3.6	3.1	2.7	2.4	2.2	1.8	1.5	1.4	1.2	1.1
31.5	4.5	3.8	3.2	2.8	2.5	2.3	1.9	1.6	1.4	1.3	1.1
33.0	4.8	4.0	3.4	3.0	2.6	2.4	2.0	1.7	1.5	1.3	1.2
34.5	5.0	4.1	3.5	3.1	2.8	2.5	2.1	1.8	1.6	1.4	1.2
36.0	5.2	4.3	3.7	3.2	2.9	2.6	2.2	1.9	1.6	1.4	1.3
37.5	5.4	4.5	3.9	3.4	3.0	2.7	2.3	1.9	1.7	1.5	1.4
39.0	5.6	4.7	4.0	3.5	3.1	2.8	2.3	2.0	1.8	1.6	1.4
40.5	5.8	4.9	4.2	3.6	3.2	2.9	2.4	2.1	1.8	1.6	1.5
42.0	6.0	5.0	4.3	3.8	3.4	3.0	2.5	2.2	1.9	1.7	1.5
43.5	6.3	5.2	4.5	3.9	3.5	3.1	2.6	2.2	2.0	1.7	1.6
45.0	6.5	5.4	4.6	4.1	3.6	3.2	2.7	2.3	2.0	1.8	1.6

Source: adapted from "Determining Vehicle Change Intervals", ITE Journal, May 1985.

5. TRAFFIC SIGNAL INDICATIONS

Traffic signal indications are described and illustrated for traffic signal heads which govern "left-turn lanes" and "other than left-turn lanes" as well as for traffic signal heads "shared" by motorists in all lanes. No attempt was made to define the circumstances under which these "shared" signal heads should be used or where traffic signal heads should be placed in circumstances where such traffic signal heads would govern specific lanes. A project entitled "Uniform Traffic Signal Display" (Project Number 158), under the auspices of the Council on Uniform Traffic Control Devices for Canada, Technical and Research Committee, is addressing the requirements in this regard. There are, however, cases where signal indications for some of the phasing alternatives should only be used where left-turn lanes are available. The exhibits for these phasing alternatives do not include proposals for "shared" signal heads.

Exhibits 1 to 9 illustrate the traffic signal indications proposed for the nine basic phasing alternatives, as follows:

(a) Alternatives in which there may be "shared" traffic signal indications:

PROTECTED/PERMISSIVE
Advanced Green

PERMISSIVE/PROTECTED
Extended Green

PROTECTED/PERMISSIVE
Leading Simultaneous Left Turn

PERMISSIVE/PROTECTED
Lagging Simultaneous Left Turn

(b) Alternatives in which there should be no "shared" traffic signal indications:

EXCLUSIVE PROTECTED
Leading Exclusive Protected Left Turn
Lagging Exclusive Protected Left Turn
Advanced Exclusive Protected Left Turn
Extended Exclusive Protected Left Turn

(c) An infrequently used phasing alternative in which there may be "shared" traffic signal indications:

SEPARATE PROTECTED LEFT TURN

Each exhibit contains a definition of the above terms which identifies the features of the various phasing alternatives.

The Technical and Research Committee of the Council on Uniform Traffic Control Devices for Canada will be considering the practices proposed in this report for incorporation as revisions to the Canadian Manual of Uniform Traffic Control Devices.

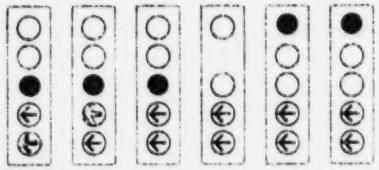
Exhibit 1
TRAFFIC SIGNAL INDICATIONS
FOR
PROTECTED PERMISSIVE
ADVANCED
LEFT-TURN PHASING

ADVANCED GREEN-- A protected left turn, during which all traffic on the principal approach may enter the intersection, is provided and is followed by permissive left turns during an interval in which all traffic on the principal approach and in the opposing direction is permitted to enter the intersection.

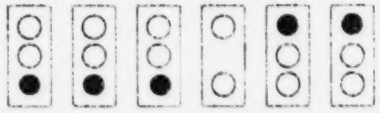
* The PRINCIPAL APPROACH is the street approach which is favoured with a signal phase to accomodate a left-turn movement.

PRINCIPAL APPROACH *

SIGNAL HEADS
GOVERNING LEFT-TURN
LANE ONLY

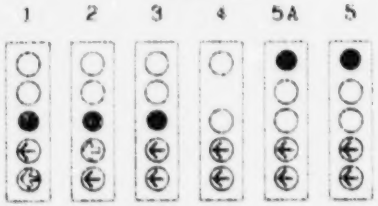


SIGNAL HEADS
GOVERNING OTHER
THAN LEFT-TURN LANES



OPPOSITE PRINCIPAL APPROACH

SHARED SIGNAL HEADS



5A is an optional interval which, if used, would be the "all red" portion of the change interval

Interval 5 would normally be the green for the cross street approach

Exhibit 2

TRAFFIC SIGNAL INDICATIONS
FOR
PERMISSIVE PROTECTED
EXTENDED
LEFT-TURN PHASING

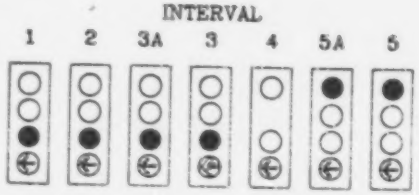
* The PRINCIPAL APPROACH is the street approach which is favoured with a signal phase to accomodate a left-turn movement.

NOTE: This phasing alternative should NOT be used where the opposing left-turn movement is allowed.

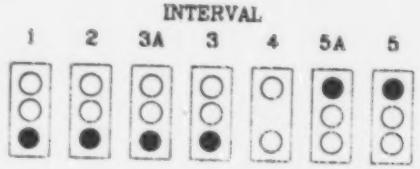
EXTENDED GREEN- Permissive left turns are allowed during an interval in which all traffic in the same direction and in the opposing direction is permitted to enter the intersection, followed by an interval with a protected left turn during which all traffic on the principal approach only may enter the intersection.

PRINCIPAL APPROACH *

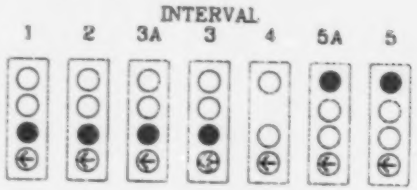
SIGNAL HEADS
GOVERNING LEFT-TURN
LANE ONLY.



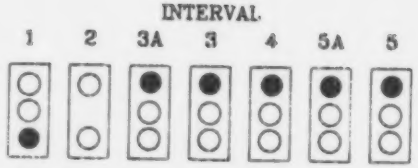
SIGNAL HEADS
GOVERNING OTHER
THAN LEFT-TURN LANES



SHARED SIGNAL HEADS



OPPOSITE PRINCIPAL APPROACH



3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

5A is an optional interval which, if used, would be the "all red" portion of the change interval.

Interval 5 would normally be the green for the cross street approach.

Exhibit 3

TRAFFIC SIGNAL INDICATIONS
FOR
PROTECTED PERMISSIVE
LEADING SIMULTANEOUS
LEFT-TURN PHASING

• BOTH APPROACHES are favoured with a concurrent signal phase to accomodate a left-turn movement.

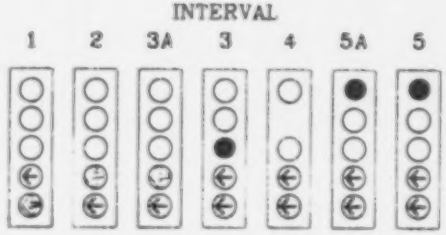
Subject to the following, both approaches will have identical signal indications.

When the left-turn phase is actuated and one of the opposing left-turn phases is not "called", the signal indications would be the same as for the protected/ permissive advanced left-turn phasing (see Exhibit 1).

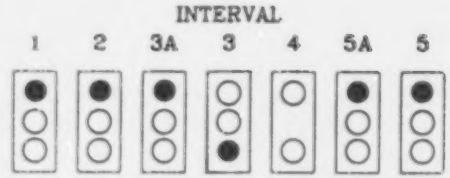
LEADING SIMULTANEOUS LEFT TURN- A protected left turn, for traffic from opposing directions entering the intersection simultaneously, is provided and is followed by permissive left turns during an interval in which all traffic in the same direction and in the opposing direction is permitted to enter the intersection.

BOTH APPROACHES •

SIGNAL HEADS
GOVERNING LEFT-TURN
LANE ONLY.



SIGNAL HEADS
GOVERNING OTHER
THAN LEFT-TURN LANES



3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

5A is an optional interval which, if used, would be the "all red" portion of the change interval.

Interval 5 would normally be the green for the cross street approach.

SHARED SIGNAL HEADS

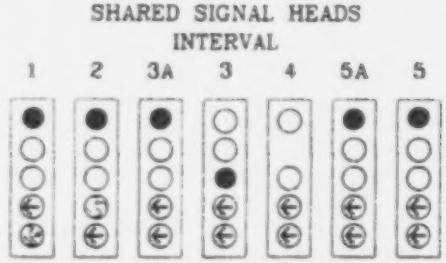


Exhibit 4

TRAFFIC SIGNAL INDICATIONS
FOR
PERMISSIVE PROTECTED
LAGGING SIMULTANEOUS
LEFT-TURN PHASING

• BOTH APPROACHES are favoured with a concurrent signal phase to accomodate a left-turn movement.

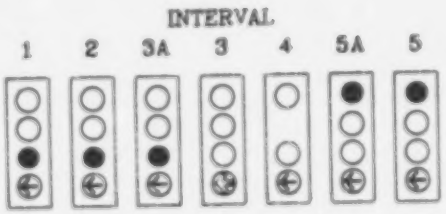
Subject to the following, both approaches will have identical signal indications.

When the left-turn phase is actuated and one of the opposing left-turn phases is not "called", the signal indications would be the same as for the permissive/ protected extended left-turn phasing (see Exhibit 2).

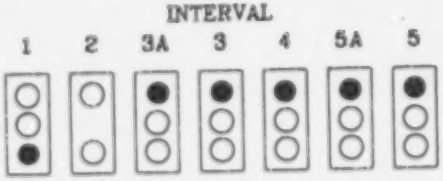
LAGGING SIMULTANEOUS LEFT TURNS- Permissive left turns may be made during an interval in which all traffic in the same direction and in the opposing direction is permitted to enter the intersection followed by an interval during which protected simultaneous left turns may enter the intersection from opposing approaches.

BOTH APPROACHES •

SIGNAL HEADS
GOVERNING LEFT-TURN
LANE ONLY.



SIGNAL HEADS
GOVERNING OTHER
THAN LEFT-TURN LANES



3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

5A is an optional interval which, if used, would be the "all red" portion of the change interval.

Interval 5 would normally be the green for the cross street approach.

SHARED SIGNAL HEADS

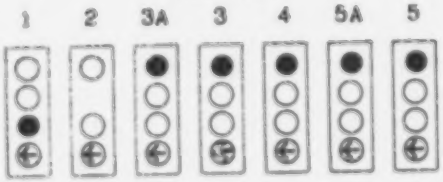


Exhibit 5

TRAFFIC SIGNAL INDICATIONS FOR EXCLUSIVE PROTECTED LEADING SIMULTANEOUS LEFT TURN PHASING

• BOTH APPROACHES are favoured with a concurrent signal phase to accomodate a left-turn movement.

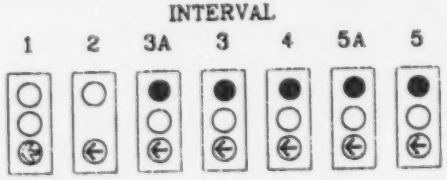
Subject to the following, both approaches will have identical signal indications.

When the left-turn phase is actuated and one of the opposing left-turn phases is not "called", the signal indications would be the same as for the exclusive/ protected advanced left-turn phasing (see Exhibit 7).

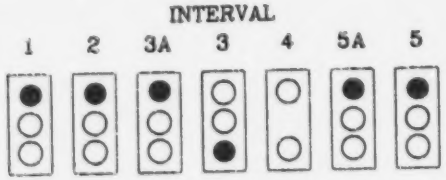
LEADING EXCLUSIVE PROTECTED LEFT TURN- A protected left turn, for traffic from opposing directions entering the intersection simultaneously, is provided and is followed by an interval in which other traffic, excluding left turns, in the same direction and in the opposing direction is permitted to enter the intersection.

BOTH APPROACHES •

SIGNAL HEADS GOVERNING LEFT--TURN LANE ONLY



SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES



3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

5A is an optional interval which, if used, would be the "all red" portion of the change interval.

Interval 5 would normally be the green for the cross street approach.

OPTION

SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES

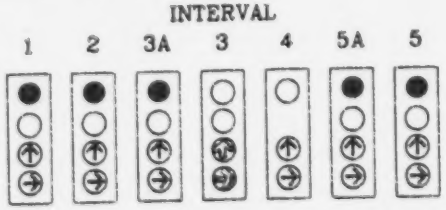


Exhibit 6

TRAFFIC SIGNAL INDICATIONS FOR EXCLUSIVE PROTECTIVE LAGGING SIMULTANEOUS LEFT-TURN PHASING

• BOTH APPROACHES are favoured with a concurrent signal phase to accomodate a left-turn movement.

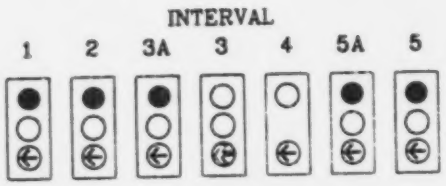
Subject to the following, both approaches will have identical signal indications.

When the left-turn phase is actuated and one of the opposing left-turn phases is not "called", the signal indications would be the same as for the exclusive/ protected extended left-turn phasing (see Exhibit 8).

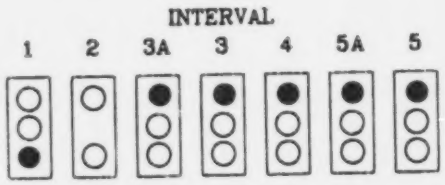
LAGGING EXCLUSIVE PROTECTED LEFT TURN- A protected left turn, for traffic from opposing directions entering the intersection simultaneously, is provided and is preceded by an interval in which other traffic, excluding left turns, in the same direction and in the opposing direction is permitted to enter the intersection.

BOTH APPROACHES •

SIGNAL HEADS GOVERNING LEFT-TURN LANE ONLY



SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES



3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

5A is an optional interval which, if used, would be the "all red" portion of the change interval.

Interval 5 would normally be the green for the cross street approach.

OPTION

SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES

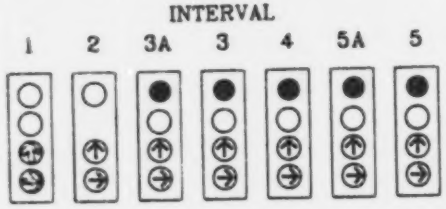


Exhibit 7

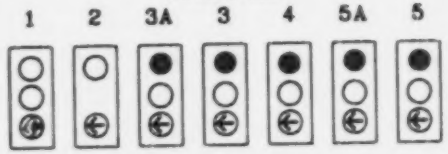
TRAFFIC SIGNAL INDICATIONS FOR EXCLUSIVE PROTECTED ADVANCED LEFT-TURN PHASING

ADVANCED EXCLUSIVE PROTECTED LEFT TURN- A protected left turn, for traffic entering the intersection from one approach only, is provided while allowing concurrent through and right-turning traffic on the same approach and is followed by an interval in which other traffic, excluding left turns, in the same direction and in the opposing direction is permitted to enter the intersection.

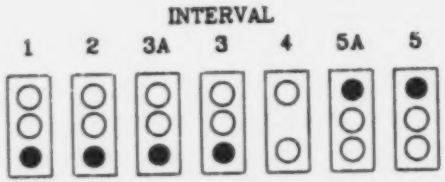
* The PRINCIPAL APPROACH is the street approach which is favoured with a signal phase to accomodate a left-turn movement.

PRINCIPAL APPROACH *

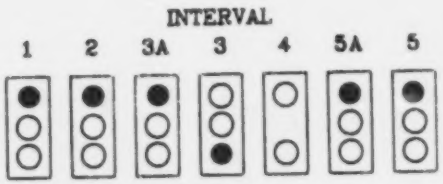
SIGNAL HEADS GOVERNING LEFT-TURN LANE ONLY.



SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES



OPPOSITE PRINCIPAL APPROACH



3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

5A is an optional interval which, if used, would be the "all red" portion of the change interval.

Interval 5 would normally be the green for the cross street approach.

OPTION
SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES

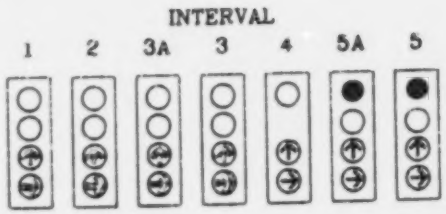


Exhibit 8

TRAFFIC SIGNAL INDICATIONS
FOR
EXCLUSIVE PROTECTED
EXTENDED
LEFT-TURN PHASING

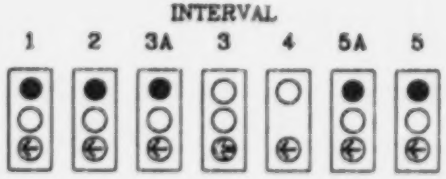
* The PRINCIPAL APPROACH is the street approach which is favoured with a signal phase to accomodate a left-turn movement.

NOTE: This phasing alternative should NOT be used where the opposing left-turn movement is allowed.

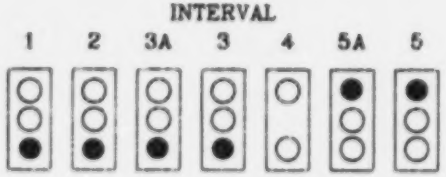
EXTENDED EXCLUSIVE PROTECTED LEFT TURN- A protected left turn, for traffic entering the intersection from one approach only, is provided while allowing concurrent through and right-turning traffic on the same approach and is preceded by an interval in which other traffic, excluding left turns, in the same direction and in the opposing direction is permitted to enter the intersection.

PRINCIPAL APPROACH *

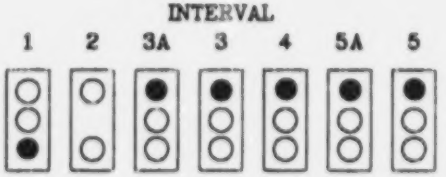
SIGNAL HEADS
GOVERNING LEFT-TURN
LANE ONLY.



SIGNAL HEADS
GOVERNING OTHER
THAN LEFT-TURN LANES

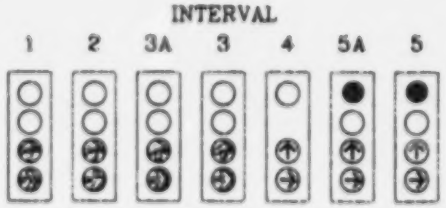


OPPOSITE PRINCIPAL APPROACH



OPTION

SIGNAL HEADS
GOVERNING OTHER
THAN LEFT-TURN LANES



3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

5A is an optional interval which, if used, would be the "all red" portion of the change interval.

Interval 5 would normally be the green for the cross street approach.

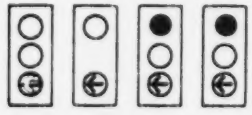
Exhibit 9
TRAFFIC SIGNAL INDICATIONS FOR SEPARATE PROTECTED LEFT-TURN PHASING

* The PRINCIPAL APPROACH is the street approach which is favoured with a signal phase to accomodate a left-turn movement.

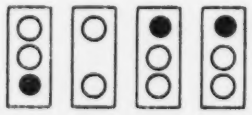
SEPARATE PROTECTED LEFT TURN- All traffic, including the left turns, is directed to enter the intersection from one approach at a time while the traffic on all other approaches is stopped.

PRINCIPAL APPROACH *

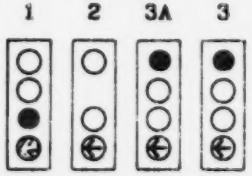
SIGNAL HEADS GOVERNING LEFT-TURN LANE ONLY.



SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES



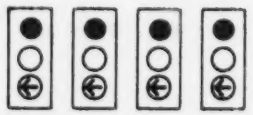
SHARED SIGNAL HEADS



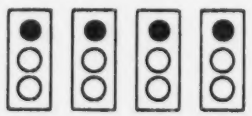
3A is an optional interval which, if used, would provide for a form of the "all red" clearance portion of the change interval.

ALL OTHER APPROACHES

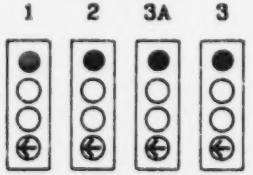
SIGNAL HEADS GOVERNING LEFT-TURN LANE ONLY.



SIGNAL HEADS GOVERNING OTHER THAN LEFT-TURN LANES



SHARED SIGNAL HEADS



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